Theodolite Basics

The function of a theodolite is to measure Angles in the Horizontal & Vertical Planes

K. Dennison

Contents

1. Theodolite features

a. Optical Reading Theodolites

b. Electronic Reading Theodolites

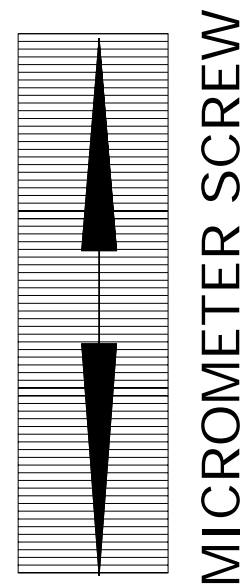
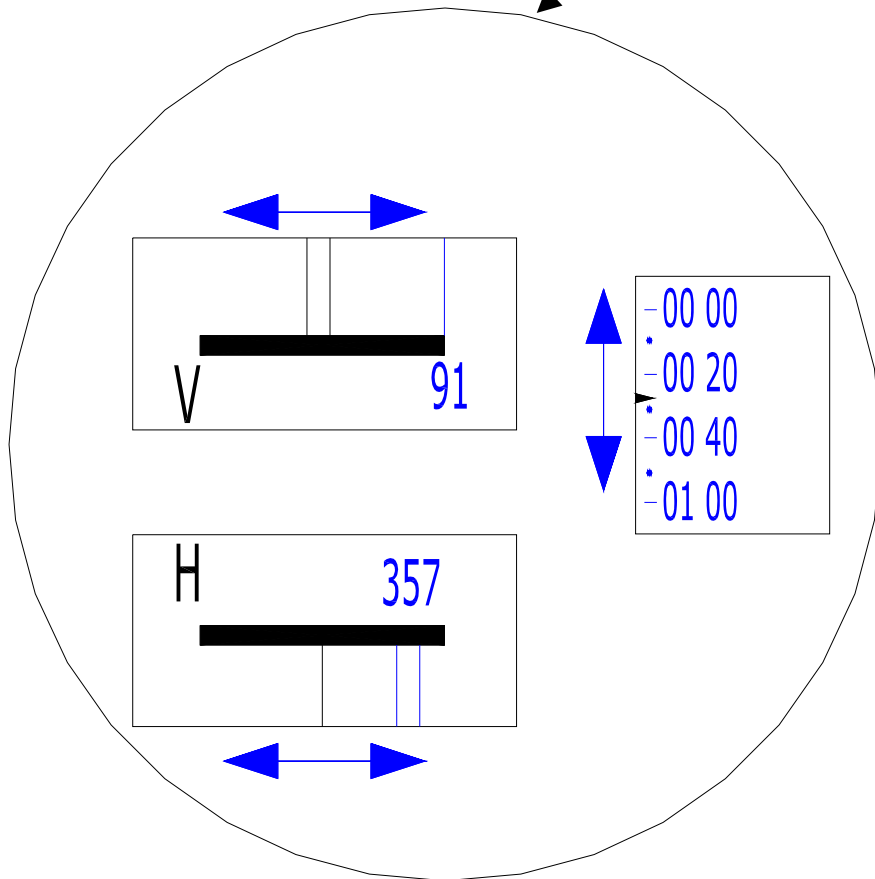
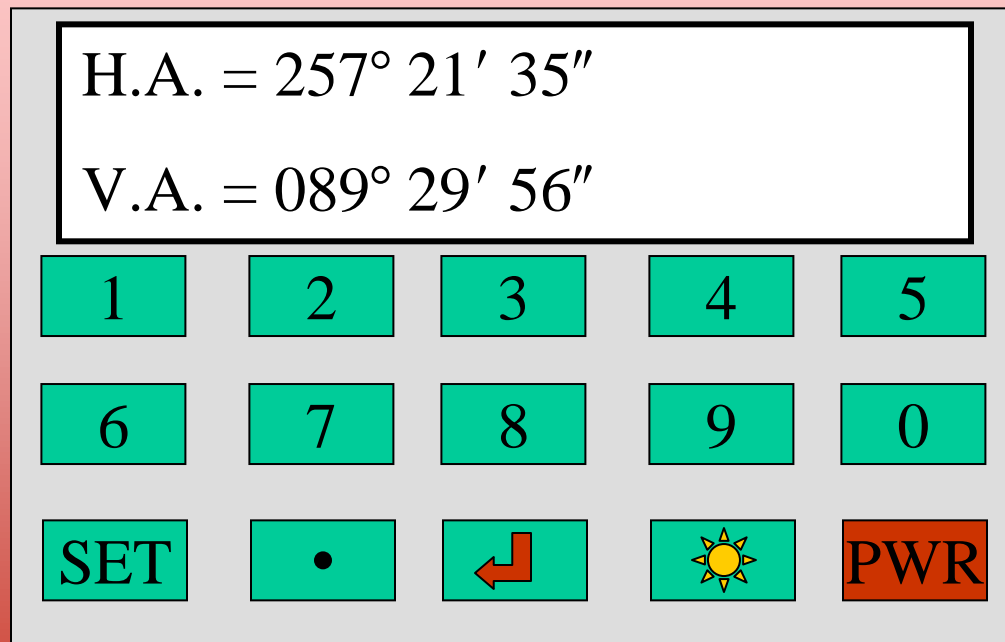
a.Optical Reading Theodolite

View through reading eyepiece

b. Electronic Reading Theodolite

H.A. = 257° 21′ 35″

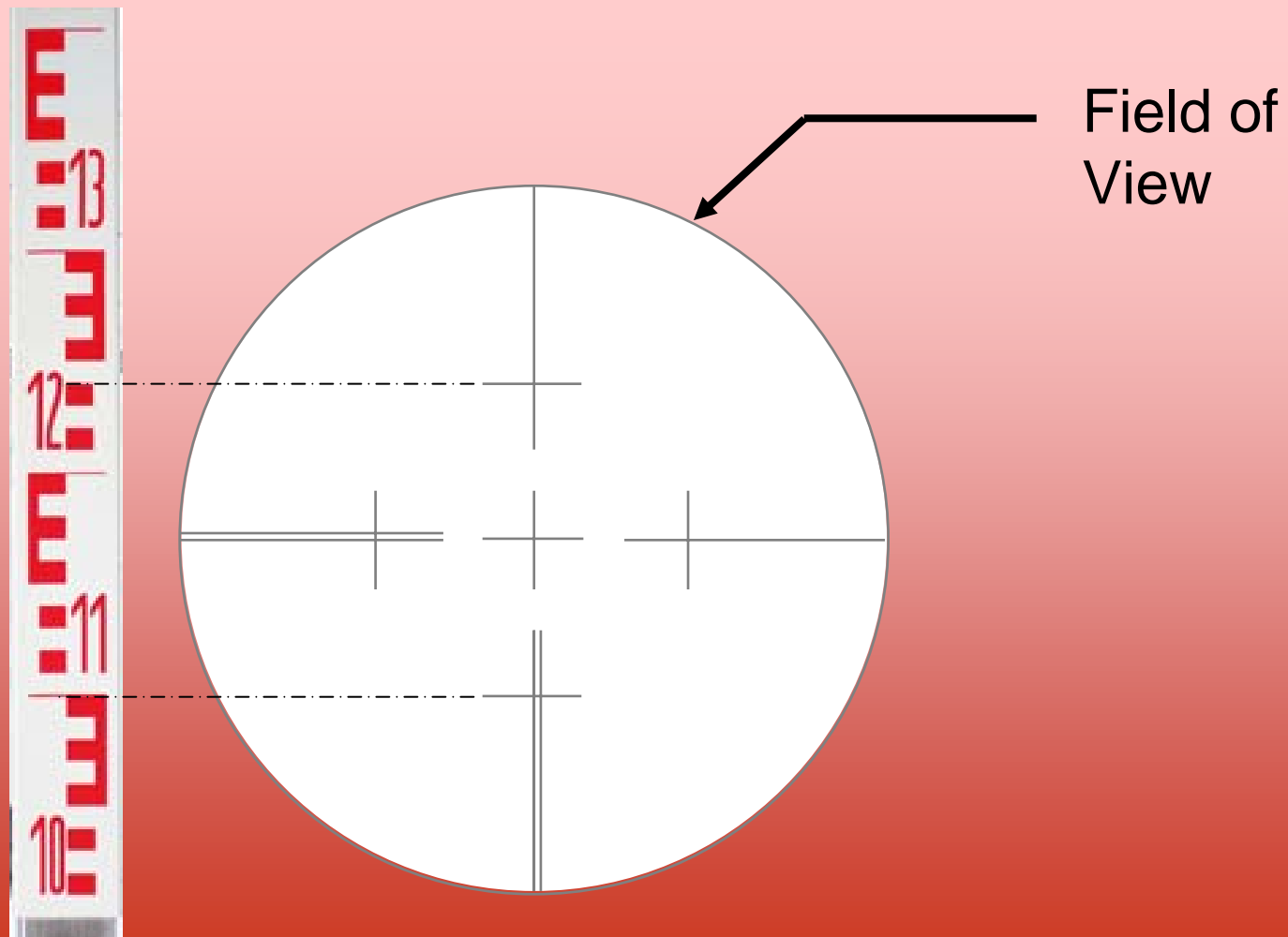
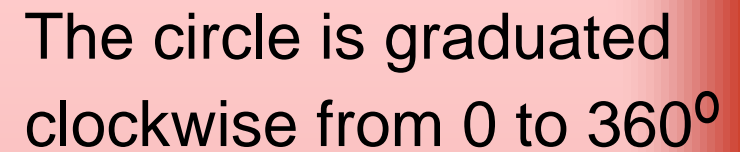
V.A. = 089° 29′ 56″

1	2	3	4	5
6	7	8	9	0
SET				PWR

LCD Display

Keys

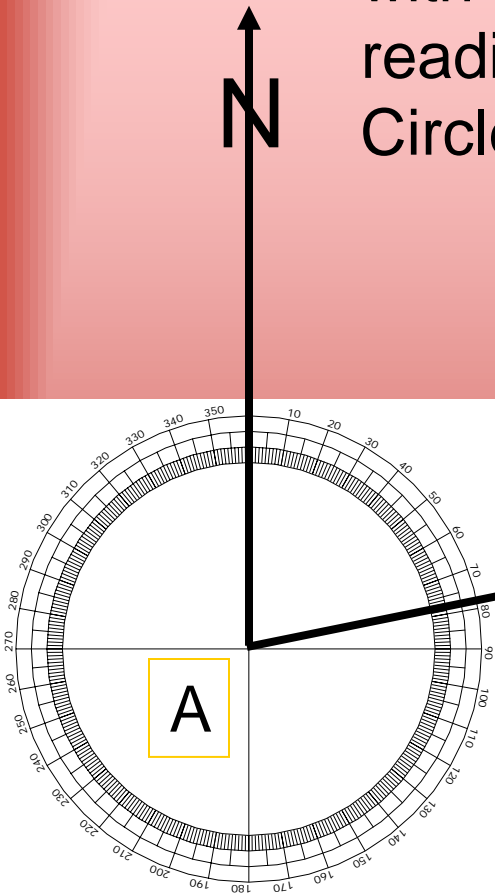
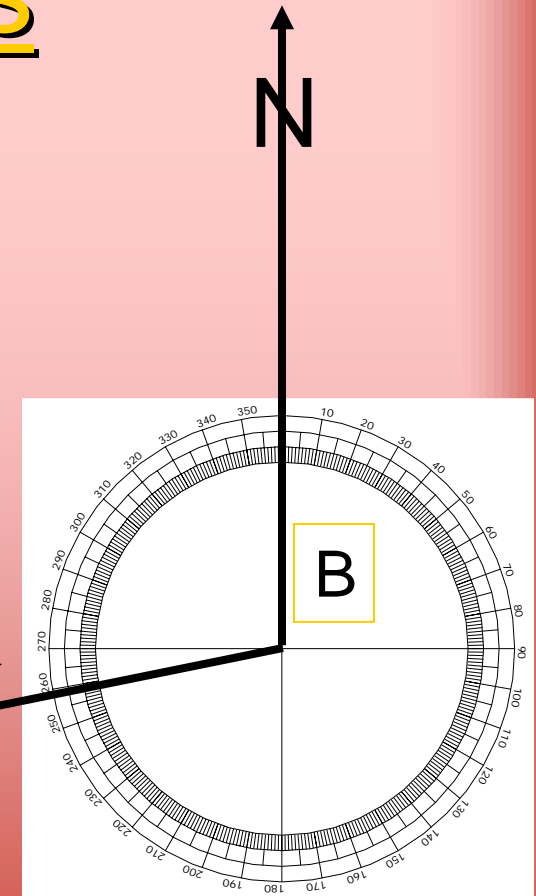
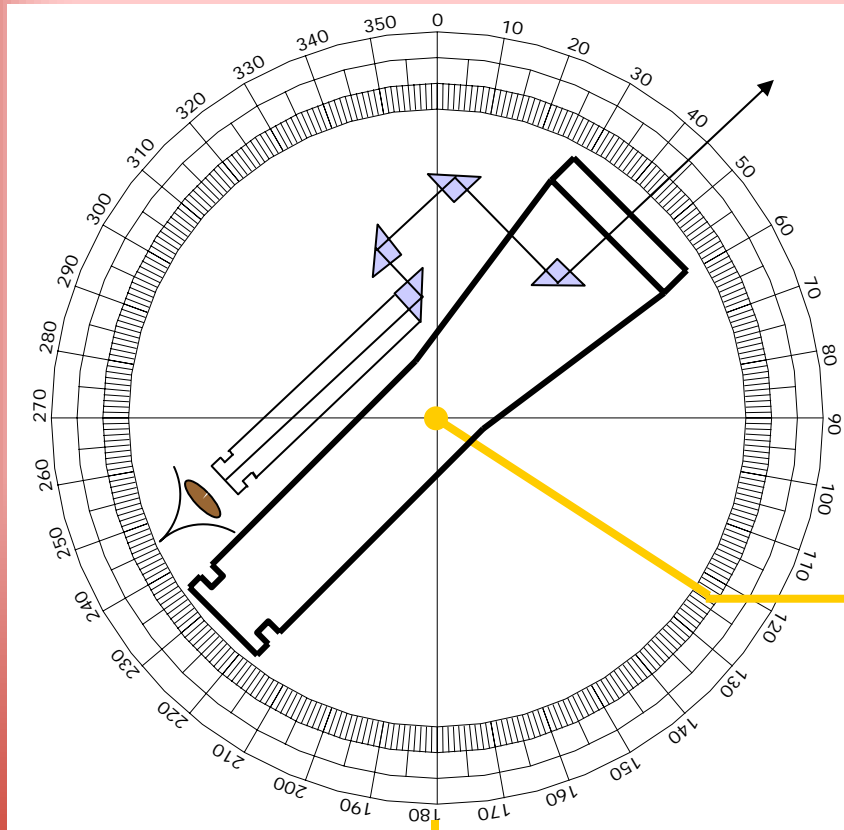
Field of view

Angles in the Horizontal Plane

The circle is graduated clockwise from 0 to 360^{o}

Subdivisions of degrees are minutes and seconds.

The centre of the circle defines the centre of the theodolite and telescope

Angles/Bearings

If Zero on the circle is aligned with North, then the circle readings are known as "Whole Circle Bearings", or "Azimuths".

Angles in the Vertical Plane

The centre of the circle defines the centre of rotation of the telescope

Plumb Line to the centre of the Earth

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Theodolite features

- This is the end of the features section
- And the the start of the operating section

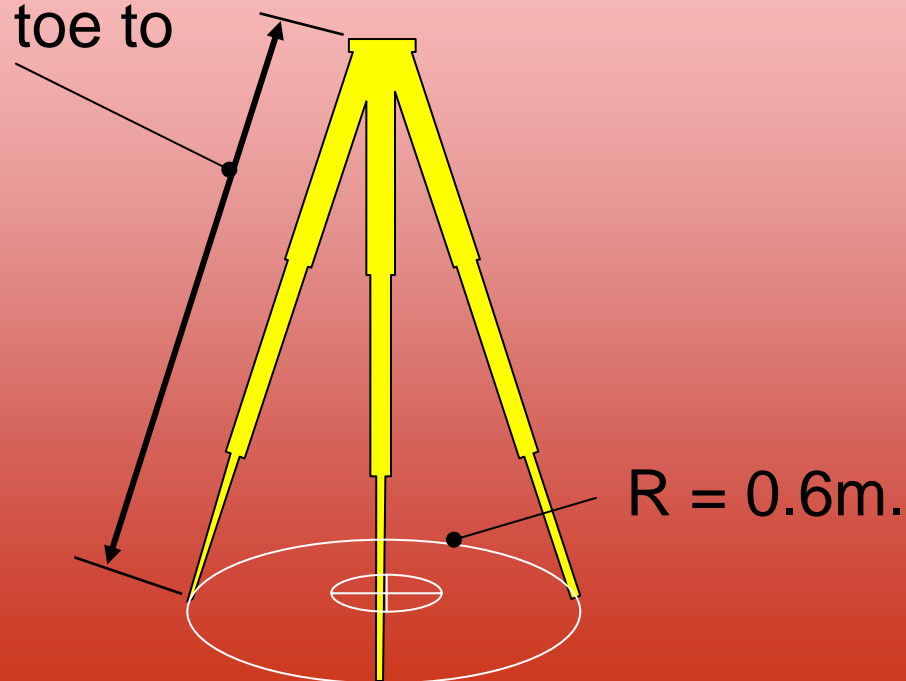
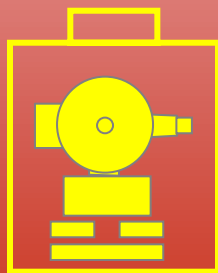
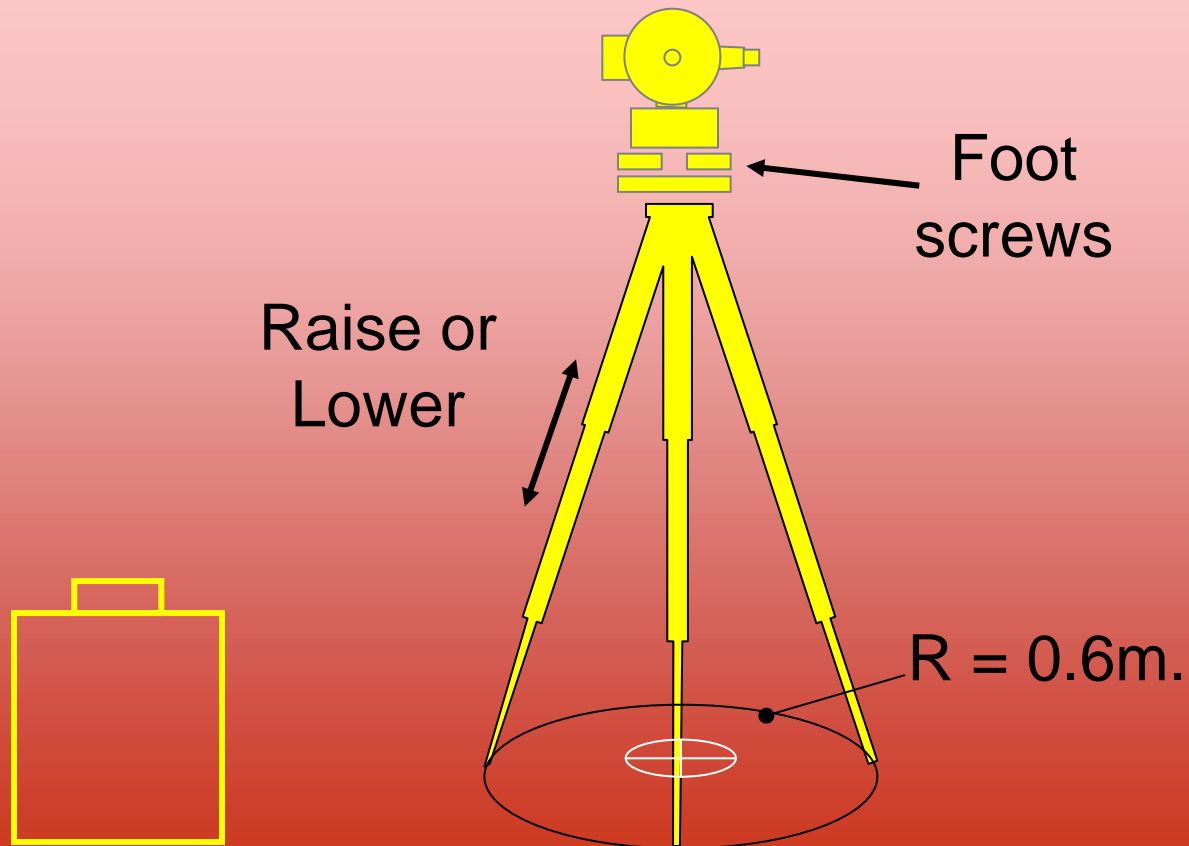
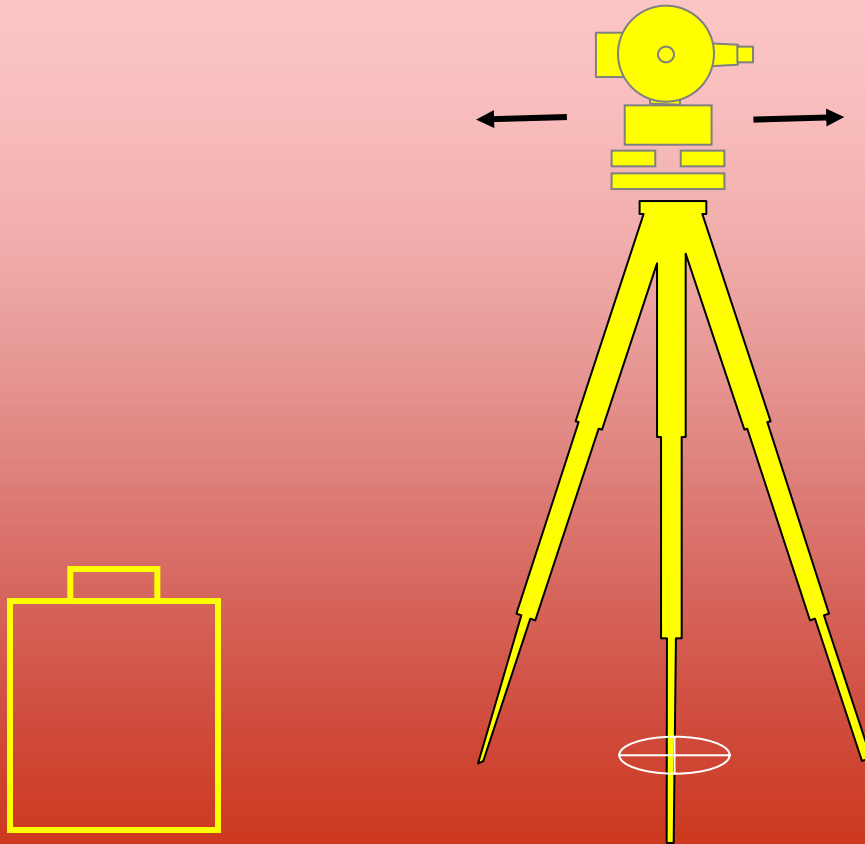
2. Operating a theodolite

1. Health, Security & safety
2. How to set up a theodolite
3. How to calibrate a theodolite

Health Safety & Security

- Your equipment must not cause an obstruction.
- You must not put yourself or others in danger.
- Do not set up over loose materials or cables.
- Do not carry an instrument on a tripod.
- Keep all accessories within arms length.
- Do not leave equipment unattended.

How to set up a theodolite (a)

A theodolite is always set up over a point.

How to set up a theodolite (b)

How to set up a theodolite (c)

Operating a theodolite

- This is the end of the operating section
- And the the start of the calibration section

3. Checks for Calibration

1. Damage
2. Plummet
3. Bubbles
4. Cross hair verticality
5. Vertical angles
6. Horizontal angles
7. Tilting axis

Checks must be done in this order

Test 1 - Damage

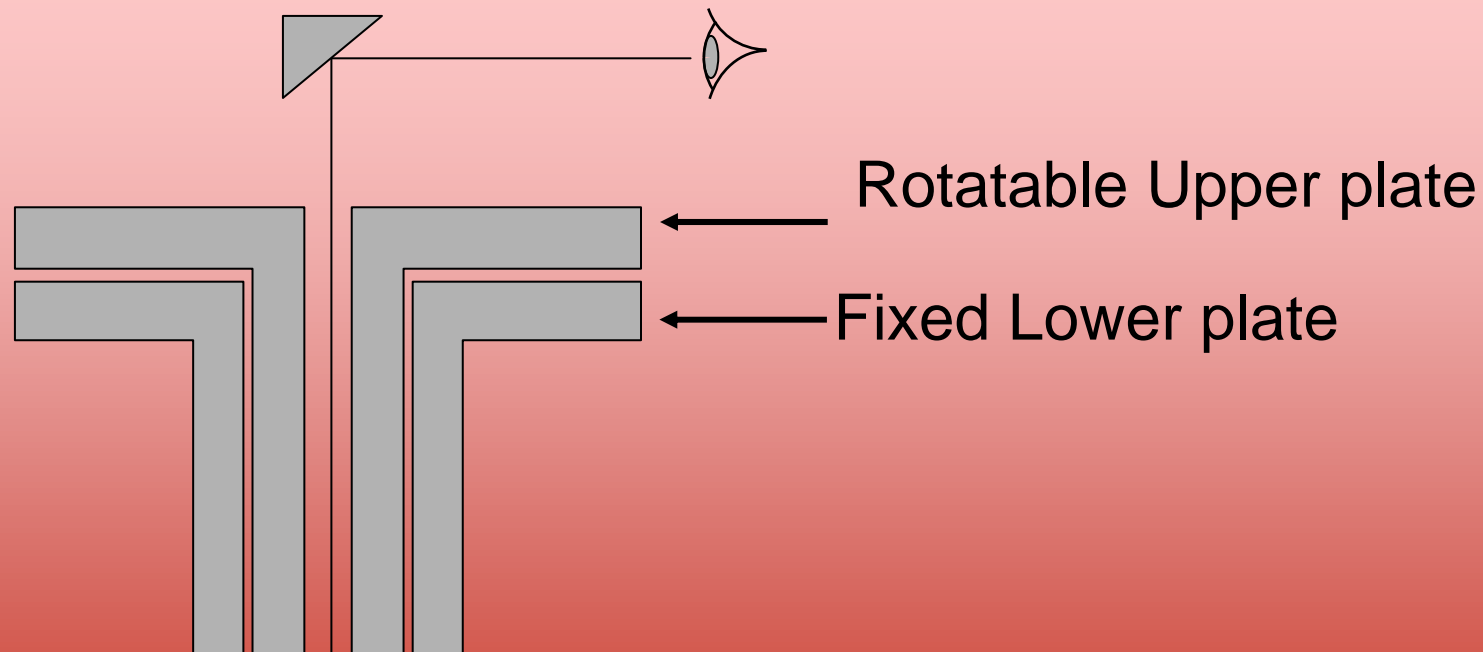
a) Obvious physical damage, (instrument & accessories).
b) Water penetration, (cloudy optics).
c) Battery condition, (if applicable).
d) Does everything work properly?

Test 2 - Plummet

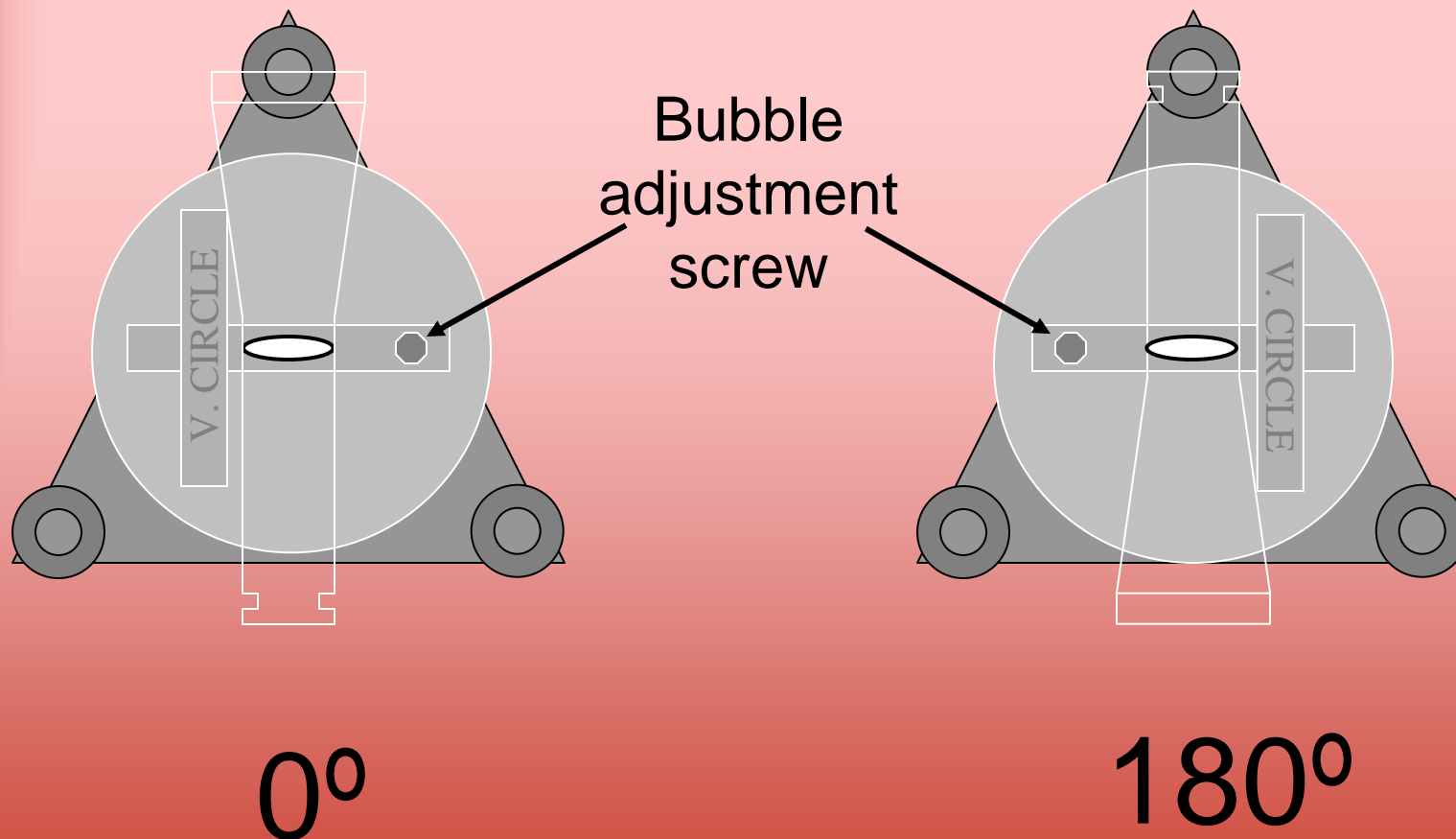
Optical Plummet or Laser Plummet

+/- 2mm at 1.5 metres

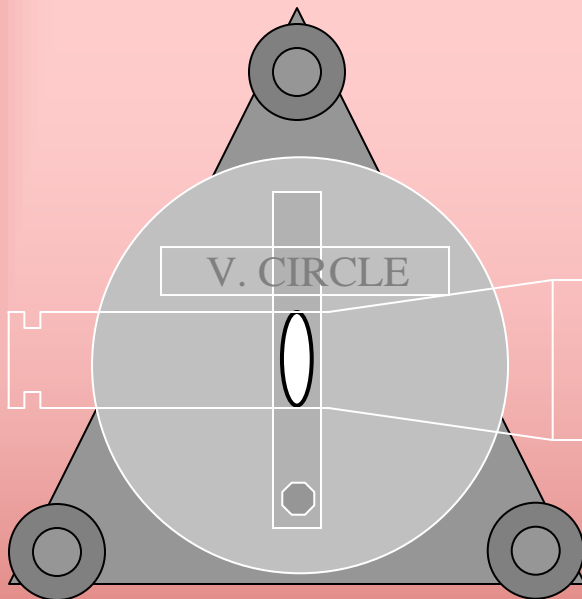
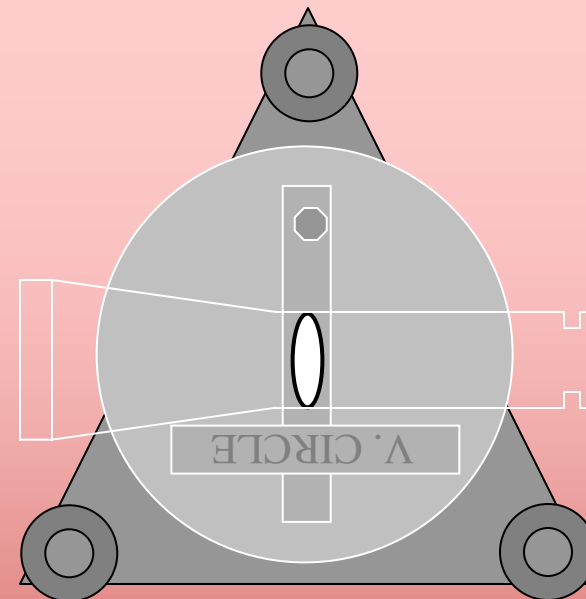
Rotatable Upper plate

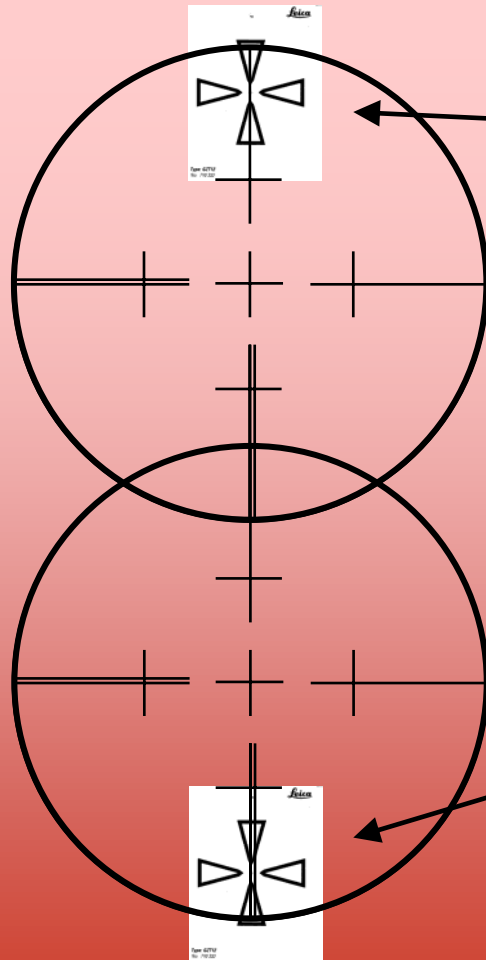
Fixed Lower plate

Test 3 – Bubbles 0° & 180°

0º

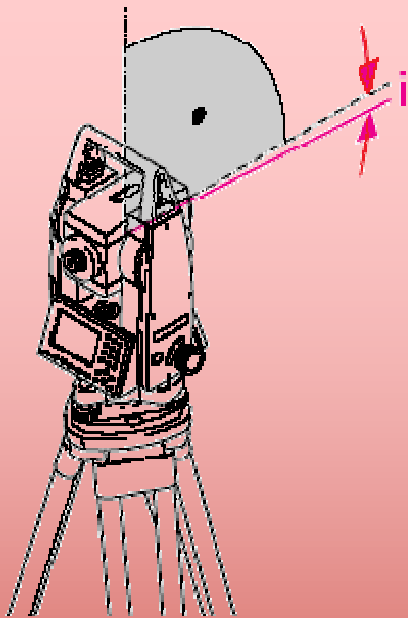
180º

Test 3 – Bubbles 90° & 270°

90º

270º

Allowable error is 2 divisions

Test 4 Cross Hair Verticality

Bisect a clear object at the top of the field of view

Elevate the telescope and check that the vertical crosshair still bisects the mark.

Test 5 Angle Corrections

V Index error	H Index error	T Axis error
10” for 1” inst.	10” for 1” inst.	
24” for 6” inst.	24” for 6” inst.	
60” for 20” inst.	60” for 20” inst.	

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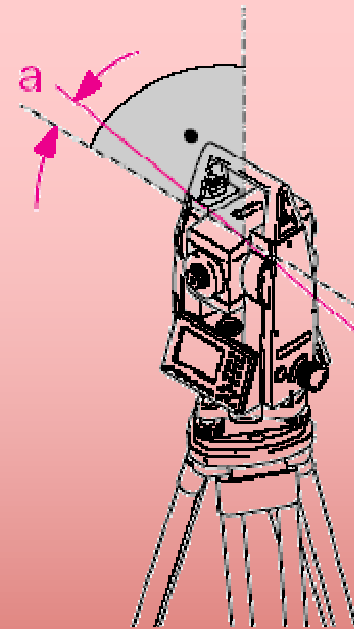
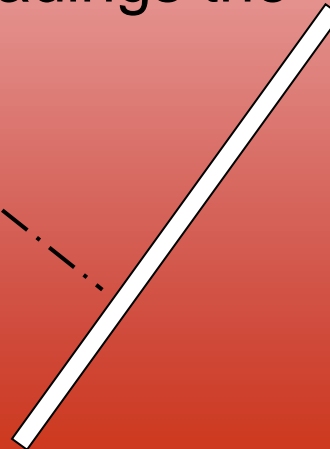
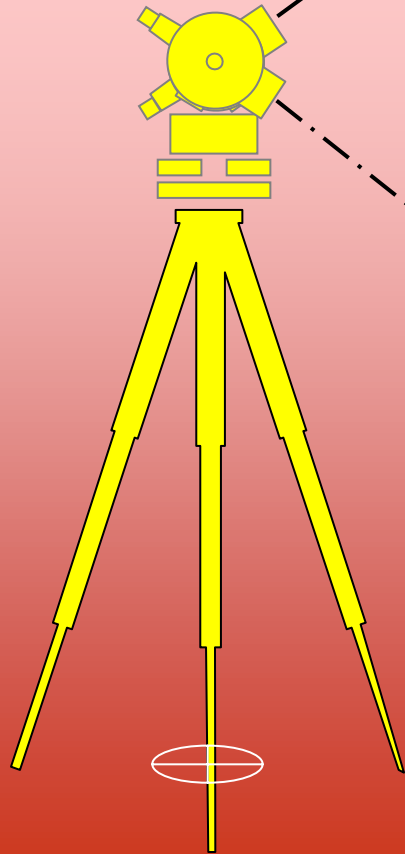
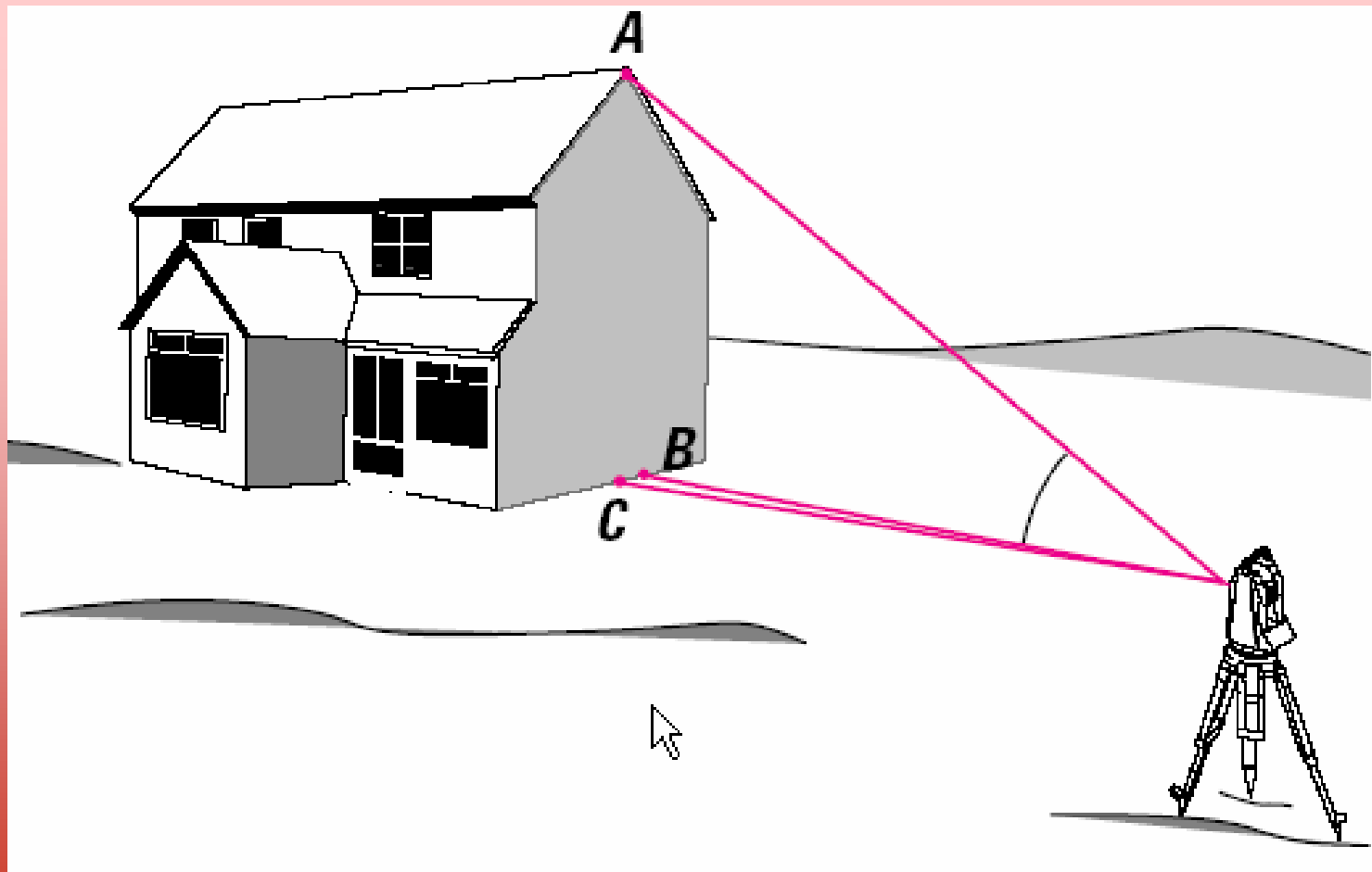

Test 5 – Vertical angles

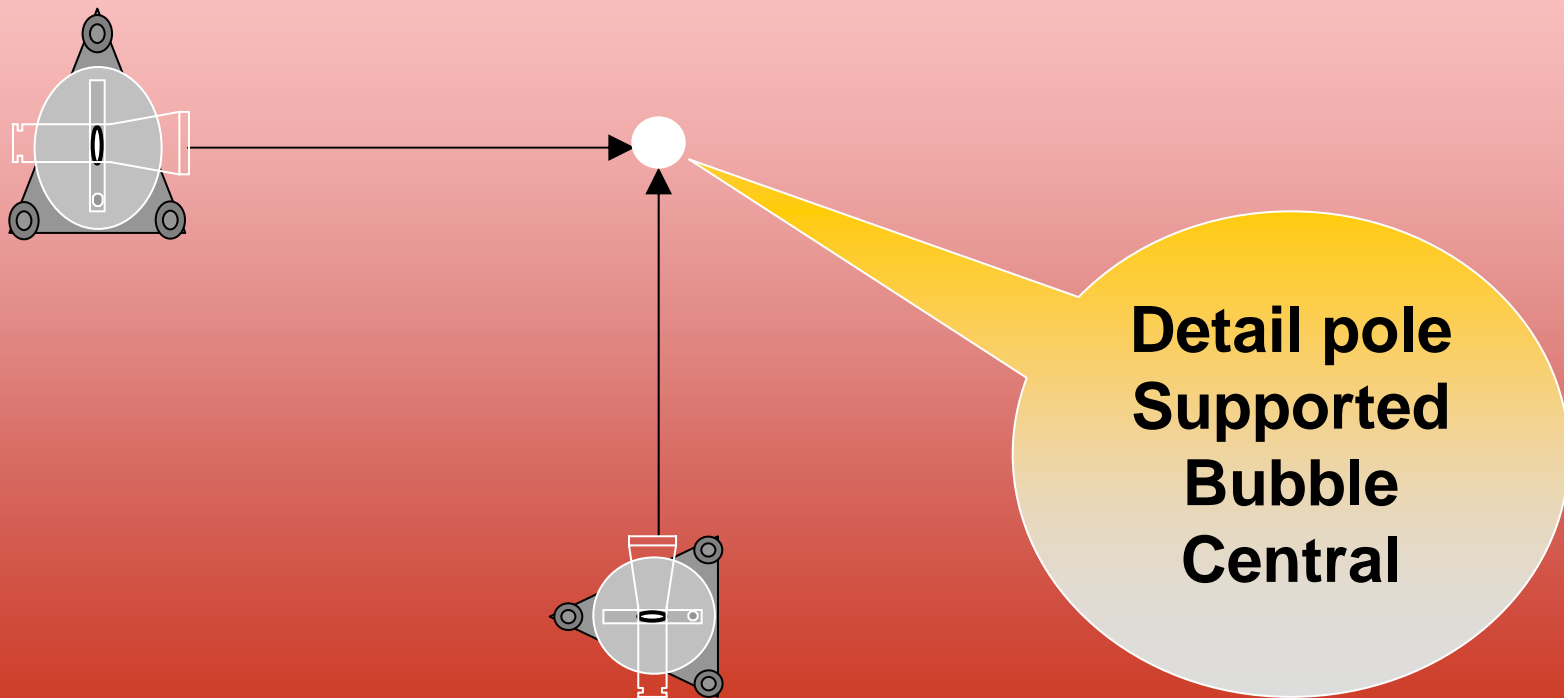
- Bisect a clear object about 100m. distant.
- Record the vertical circle reading.
- Change face.
- Bisect the same object as before.
- Record the vertical circle reading.
- The sum of the readings should be 360º 00º 00º +/- the manufacturer’s tolerance.

Test 6 – Horizontal angles

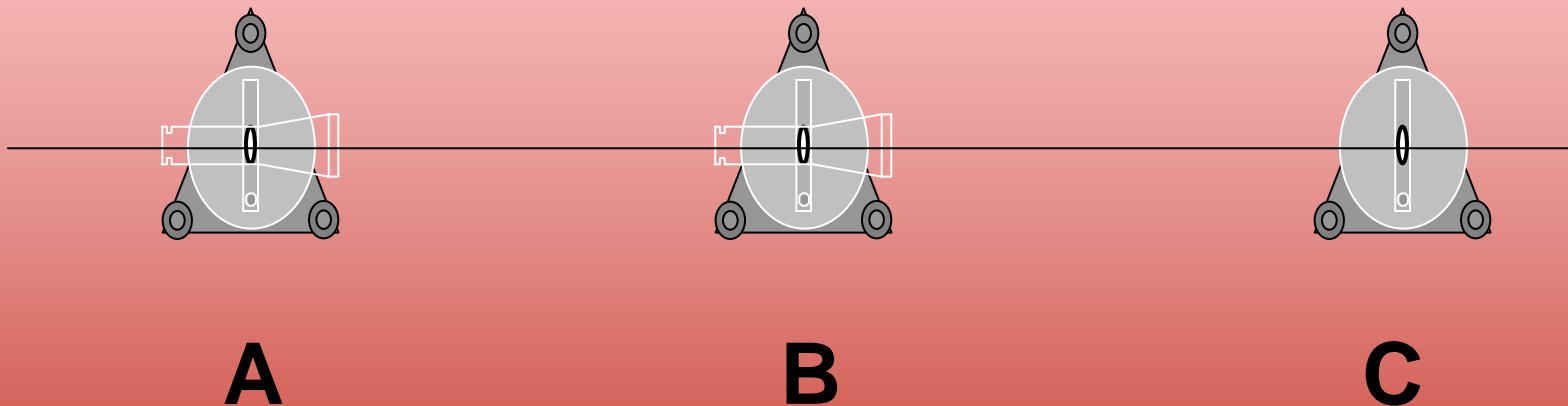
- Bisect a clear object about 100m. distant.
- Record the horizontal circle reading.
- Change face.
- Bisect the same object as before.
- Record the horizontal circle reading.
- The difference between the readings should be 180º 00º 00º $\mp$ the manufacturer's tolerance.

Test 7 Tilting Axis Check

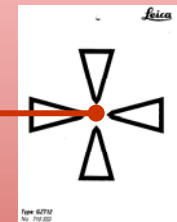
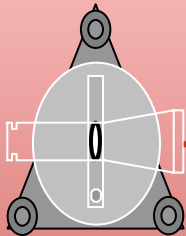
1. Sight a high object
2. Read a low level staff
3. Change face
4. Repeat 1, and 2
5. Are both readings the same?

Test 7 Tilting Axis Check

Detail Pole Check

1. Check straightness of pole by rolling
2. Set two theodolites at 90 degrees

EDM Baseline Check

1. Set out a baseline of 3 stations
2. Setup at A, measure A to C
3. Setup at B, measure B to A, and B to C
4. A to C = A to B - B to C

A **B** **C**

This does NOT check errors proportional to the distance
Ideally check a known distance

EDM Alignment check Check

1. Bisect a target 15 metres away
2. Switch on the laser pointer
3. Check that the laser spot illuminates the cross

Practical Exercise

- To test your learning you will be required to set up a theodolite over a point and calibrate the instrument.
- This is a test for each student individually.

THE END

Slide 1

- Angles are measured using the sexagesimal system.
- A circle is divided into 360 degrees.
- A degree is further divided into 60 minutes.
- A minute is further divided into 60 seconds.

Slide 3.

- It is advisable to learn on an optical reading theodolite before progressing to electronic reading theodolites.
- If you can use an optical reading theodolite, you can use electronic reading theodolites.
- Optical reading theodolites are still widespread in Industry.
- The only difference between an electronic theodolite and a conventional theodolite is the reading and angle setting system.

Slide 4

- This is the view through the reading eyepiece.
- I have coloured blue the items which move when the micrometer screw is rotated.
- To set the horizontal angle to a certain value is an involved procedure.
- To read the angles is not easy. This is one of the easier ones. (Pentax).
- Turn the micrometer knob until the movable (blue) lines are central on the static black lines.

Slide 5

- To set the horizontal angle to a certain value is very easy.
- To read the angles is also very easy.

Slide 6

- This is what you see when you look through the telescope.
- The field of view is reduced for spectacle wearers.
- The central vertical X hair is the reference for the horizontal angle.
- The central horizontal X hair is the reference for the vertical angle.
- The small X hairs subtend an angle of 0.573 degrees, i.e. 1/100.
- (In this case, 1.771 – 1.349 = 0.422. Therefore the distance is 0.422*100 = 42.2 metres).

Slide 7

- This is a birds-eye view of the horizontal circle. The circle is mounted horizontally and is used to measure angles in the horizontal plane.
- The circle can be clamped to either the upper rotating part of the theodolite, or the lower fixed part.
- If the circle is clamped to the fixed part, the reading changes as the theodolite rotates.
- If the circle is clamped to the rotating part, the reading does not change as the theodolite rotates.

- In this way, the reading can be set to a required value, and the theodolite then aligned with an object corresponding to that value.
- It is not possible for a theodolite to automatically align itself with North. If this is required it must be done by the operator using one of several methods.

- To measure “Whole Circle Bearings” also called “Azimuths”, or “Headings”, it is necessary to align zero on the horizontal circle with North.

Slide 8

- Correct Surveying terminology is “Whole Circle Bearing”, or “Azimuth”.
- Navigation terminology is “Heading”.
- “Bearing” is often used but should be avoided due to confusion with “Quadrant Bearing”, (Points of the compass).

- Install 2 pegs “A” and “B”.
- Set the theodolite at “A” and align zero on the circle with North.
- Theodolite horizontal circle reading is 78 degrees = “WCB”.
- Move the theodolite to “B”, sight “A” and set the horizontal circle to 258 degrees.
- Zero on the circle is now aligned with North, and all circle readings are now WCB’s.

Slide 9

- This circle is mounted vertically and is used to measure angles in the vertical plane. Zero is at the top.
- The centre of this circle defines the centre of rotation of the telescope.
- The vertical axis of the theodolite is determined by a straight line from the centre of the earth, through the centre of the theodolite, to the Zenith, i.e. a “Plumb Line” and is determined by an internal pendulum device called a ”compensator”.
- Angles in the vertical plane are always measured from the Zenith.
- As you can see, the line of sight is horizontal when the circle reading is 90 degrees, or 270 degrees.

Slide 13

The procedure.

- Extend the tripod legs to no more than your toe to collarbone distance.
- Place the tripod centrally over the ground point.
- Position the points of the legs about 0.6 metres from the ground point, and equally spaced from each other.
- Press the tripod legs into the ground using the foot pegs.
- Ensure all clamps are tight.
- Remove the theodolite from its box, and screw onto the tripod.
- Close the lid of the theodolite box to keep out rain & dust.

Slide 14

- Position the plummet beam or X-hairs on the ground mark, (+/- 25mm.) by rotating the foot screws or by moving one tripod leg at a time.

- Press the tripod legs into the ground using the foot pegs.
- Centralise the circular bubble by increasing or reducing the length of each tripod leg in turn, while keeping your foot on the foot peg of the tripod leg you are adjusting.
- Repeat for each tripod leg in turn until the circular bubble is central.
- Do not move the points of the tripod legs off the ground.
- When the circular bubble is central, position the tubular bubble parallel to two foot screws, and centralise it by turning these two foots crews by equal amounts, but in opposite directions.

- Turn the theodolite 90 degrees horizontally, and using only the remaining foot screw, centralise the tubular bubble.
- Ensure that the bubble remains central for any rotation of the theodolite.
- Minor adjustment of the foot screws might be required to achieve this.

Slide 15

- Slacken the bolt holding the theodolite to the tripod, and while looking through the optical plummet, or observing the laser spot, slide the theodolite on the tripod top until the ground point is bisected, and tighten the bolt.
- The theodolite must not be rotated during this sliding activity.
- Check that the theodolite is still level, and make any minor corrections using the foot screws.
- Check that the ground mark is still bisected, and if not repeat the sliding procedure until it is.

The set up is satisfactory when: -

- The ground mark is bisected +/-1mm.
- The tubular bubble does not move more than one division in a 360 degree rotation.
- All four tripod clamps are tight.
- The tripod is not causing an obstruction.
- The tripod is in no danger of being knocked.
- The observer is in no personal danger.

Slide 17

- It is important that checks are done in the order shown.

Slide 18

- Check this list above and terminate the calibration checks if the instrument fails. Label the instrument “Do not Use”, and arrange for a replacement.
- Proceed to the next stage on satisfactory completion of the damage checks.

Slide 19

- The Plummet is used to position the theodolite over a ground point, (either a Survey Station or a Grid Intersection).
- An Optical plummet requires the operator to focus on a ground point using a built-in eyepiece as shown. Focussing adjustment is provided at the eyepiece.
- A Laser plummet has no eyepiece. A built-in laser projects a beam downwards to a ground point. Intensity regulation is provided.
- The line of sight or laser beam must be concentric with, and parallel to, the centre of the bearing as shown.

- To check that this is so, bisect the ground point with the crosshairs or laser beam of the plummet, then rotate the theodolite 180 degrees in the horizontal plane.
- If the ground point is still bisected +/- 1mm. The plummet is in adjustment.
- Correction of errors is detailed in the manual for each instrument.
- Repeat this check after adjustment.
- It is not necessary for the theodolite to be level for the purpose of this test.

Slide 20

- When the main tubular bubble is central, the vertical axis of rotation of the theodolite must be vertical.
- Position the bubble parallel to two foot screws.

- Turn the foot screws equally, but in opposite directions until the bubble is central.
- Turn the instrument 180 degrees horizontally.
- If the bubble is still central no adjustment is needed.

Slide 21

- Repeat the above at the 90 degree & 270 degree positions, but using only the third foot screw.
- The bubble should remain central for any horizontal orientation of the theodolite.
- If adjustment is required, half the error should be removed by rotating the foot screws and half by the adjustment screws. Refer to the instrument manual.
- Repeat this check after adjustment.

Slide 22

- The line of sight of the telescope must be at 90 degrees to the horizontal axis of the theodolite.
- Tests 4 & 5 require measurements on two faces of the theodolite

Slide 23

- V Index error is the error between the plumb line and the vertical axis.
- H index error is when the angle between the line of sight and the tilting axis is not a right angle.
- T Axis error is when the tilting, (trunnion), axis is not horizontal.

Slide 24

- A line connecting zero and 180 degrees on the vertical circle must be vertical.
- See the manufacturer's manual for adjustment procedures.
- Repeat this check after adjustment.

Slide 25

- See the manufacturers manual for adjustment procedures.
- Repeat this check after adjustment.

Slide 26

- The instrument must be precisely level for this test.
- Adjustment is normally only provided for trunnion axis dislevelment on high precision instruments.

Slide 28

- Roll the detail pole on a kitchen counter top or similar flat surface.
- The detail pole must be rigidly supported at the top

Slide 29

- A, B, and C must be in a straight line, say 10 meters apart.
- Ideally use three tripods and two targets.